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Indian Standard

CODE OF PRACTICE FOR TREATMENT OF WATER FOR LOCOMOTIVE BOILERS

(First Revision)

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Indian Standard

CODE OF PRACTICE FOR TREATMENT OF WATER FOR LOCOMOTIVE BOILERS

(*First Revision*)

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Indian Standard

CODE OF PRACTICE FOR TREATMENT OF WATER FOR LOCOMOTIVE BOILERS

(First Revision)

0. FOREWORD

0.1 This Indian Standard (First Revision) was adopted by the Indian Standards Institution on 23 December 1977, after the draft finalized by the Water Sectional Committee had been approved by the Chemical Division Council.

0.2 This standard was first published in 1964. Based on the comments received from the Railway Board, the standard is now being revised. The standard has been uptodated in the light of latest data available and experience gained during these years.

0.3 The troubles experienced in a locomotive boiler are the same as those experienced by a land boiler or a marine boiler, namely, those due to the formation of scale, corrosion, caustic embrittlement, and foaming. However, the peculiar operating conditions of the locomotive boiler, namely, its continuous mobility and the necessity of its having to take water as boiler feed at frequent intervals on its run, each probably having different characteristics, make its treatment a problem quite different from that of the other two.

0.4 Whenever possible, it should be arranged that the quality of feed water at any individual watering point does not differ markedly from the mean average for the particular section on which the locomotive is to operate. Greatly differing feed waters can lead to problems due to suspended solids and total dissolved solids which neither blowing-down within reason nor antifoam compounds can adequately control.

0.5 In preparing this standard, assistance has been derived from information and data obtained from Research, Designs and Standards Organization of the Ministry of Railways, Government of India, which is gratefully acknowledged.

0.6 For the purpose of deciding whether a particular requirement of this standard is complied with, the final value, observed or calculated, expressing the result of a test or analysis, shall be rounded off in accordance with

IS : 2-1960*. The number of significant places retained in the rounded off value should be the same as that of the specified value in this standard.

1. SCOPE

1.1 This standard lays down the methods to be adopted for the treatment of water for locomotive boilers.

2. OBJECT OF TREATMENT

2.1 The object of treatment of water for locomotive boilers is to bring about :

- a) reduction of boiler maintenance cost;
- b) increased life of tube, fire boxes, stays, etc;
- c) extension of periods between major 'shoppings';
- d) increase in locomotive availability due to extension of periods between washing out boilers; and
- e) decreased fuel consumption.

3. SOURCES OF WATER AND IMPURITIES PRESENT IN IT

3.1 Water is obtained from different sources in nature and its composition is also found to differ widely with its source. It is, therefore, necessary to study the characteristics of these supplies to treat them properly to obtain a supply of the desired quality. The usual sources of water are:

- a) *Surface Water* — from rivers, streams or lakes; and
- b) *Underground Water* — from wells and springs.

3.1.1 *Surface Water* — As water flows over the earth, it dissolves salts of sodium, potassium, calcium, magnesium, iron and aluminium, besides silica and traces of manganese and other heavy metals. In addition to these dissolved impurities, surface water, particularly river water, contains significant concentrations of various colloidal clays of siliceous origin, referred to as turbidity. The turbidity is very high in the rainy season. It also contains to a lesser degree hydrophilic and hydrophobic colloids of sewage and vegetative origin, depending on the degree of pollution from domestic and industrial waste water. It contains carbonate and non-carbonate hardness in varying proportions. Iron, if present, can be in soluble or insoluble state.

3.1.2 *Underground Water* — The character of underground water depends upon the strata through which it has passed. Usually, it contains both carbonate and non-carbonate hardness. Underground waters in general

*Rules for rounding off numerical values (revised).

are rich in free carbon dioxide and in bicarbonates. Silica content is sometimes high. In many cases iron and manganese are present along with bicarbonates.

4. TROUBLES EXPERIENCED IN LOCOMOTIVE BOILERS

4.1 The troubles experienced in locomotive boilers are due to the formation of scale, corrosion, caustic embrittlement, and priming and foaming. Dissolved gases, algae and other living matter also give troubles and should be absent.

4.1.1 Scale — This is caused principally by salts of calcium and magnesium, present in water, precipitating in the boiler and the baking of the precipitate on the tubes or plates, forming a hard scale. If calcium and magnesium salts are removed from the water before it is fed to the boiler, there would be hardly any scale. If water containing calcium and magnesium salts is fed to a boiler and certain other chemicals or products are also added so that the precipitate of calcium and magnesium is obtained as a smooth flowing non-adhering sludge, a minimum of scale would be obtained.

4.1.2 Corrosion — Corrosion is prevented by maintaining sodium carbonate and sodium hydroxide alkalinities within certain limits. Tannin or sodium sulphite is used to absorb dissolved oxygen, thereby facilitating prevention of corrosion. Corrosion is also caused by the presence of chlorides in water. It is, therefore, suggested that raw waters containing more than 300 mg/l of chlorides (as Cl) should not be used for locomotive boilers.

4.1.3 Priming and Foaming — Priming and foaming in locomotive boiler is due to a number of factors including high concentration of dissolved solids or suspended solids or both. This trouble can be prevented by some means of deconcentration, namely, blow down, washing out or water-change. The use of certain antifoam compounds retards priming and foaming considerably and with their help, much higher concentrations of dissolved solids and suspended solids can be allowed to be built up in the boiler water.

5. TREATMENT OF WATER

5.1 Treatment of water shall be done either (a) at the point where it is filled in the locomotive, or (b) in the locomotive itself.

5.1.1 Treatment at the Filling Point — The treatment at the filling point would be either (a) softening by precipitation method (see 5.1.1.2), or (b) softening by base exchange method (see 5.1.1.3). In order to select the required mode of treatment, the analysis of the feed water shall be taken into consideration. Classification of feed waters is given in Table 1.

TABLE 1 CLASSIFICATION OF FEED WATER

Sl. No.	CLASSIFICATION	TEMPORARY HARDNESS (mg/l of CaCO_3)	PERMANENT HARDNESS (mg/l of CaCO_3)
(1)	(2)	(3)	(4)
i)	Very good	0 to 150	0 to 50
ii)	Good	150 to 220	50 to 80
iii)	Fair	220 to 430	80 to 220
iv)	Bad	Over 430	Over 220

5.1.1.1 'Bad' waters require external treatment and other waters may be treated internally. For external treatment other things being equal, preference should be given to the lime-soda treatment. Base exchange treated water would cause an undue build up of causticity in the boiler. Moreover, lime-soda treatment would reduce the total dissolved solids in the feed water and thus save on blow-down and the possible use of antifoams.

5.1.1.2 Precipitation methods — In the precipitation methods, hardness and carbon dioxide are reduced, the precipitates are then separated by sedimentation and filtration. The oldest and the most widespread method of precipitation softening is the lime-soda process, hot and cold. In this process, the water is treated with hydrated lime (calcium hydroxide) and soda ash (sodium carbonate). Following are the methods:

- a) *Hydrated lime treatment* — In theory, treatment with hydrated lime reduces the calcium carbonate hardness and the uncombined carbon dioxide by precipitation in the form of calcium carbonate. At the same time the magnesium carbonate hardness is considerably reduced by precipitation in the form of magnesium hydroxide. Another reaction of a slightly different type takes place between hydrated lime and magnesium non-carbonate hardness. In this reaction the magnesium non-carbonate hardness is reduced by precipitation in the form of magnesium hydroxide and replaced by an equivalent amount of calcium non-carbonate hardness. The calcium non-carbonate hardness produced in this way together with that originally present in the raw water is removed by treatment with sodium carbonate. In practice the chemical reaction between lime and magnesium hardness may not go to completion. When waters containing sodium bicarbonate are treated with hydrated lime, the sodium bicarbonate is converted into sodium carbonate.
- b) *Sodium carbonate treatment* — Treatment with sodium carbonate causes the non-carbonate hardness to precipitate from solution in the form of calcium and magnesium carbonate. The calcium and

magnesium salts are replaced by an equivalent amount of sodium salts. Thus, by means of treatment with hydrated lime and sodium carbonate in appropriate quantities, most of the carbonate and non-carbonate hardness can be removed and a soft water produced with a hardness of approximately 10 to 40 mg/l in terms of calcium carbonate.

- c) *Coagulants* — A big advance was made in the field of precipitation softening with the introduction of coagulants. The coagulants generally used are sodium aluminate, magnesium oxide, alum, ferric sulphate, etc. The amount of coagulant used is normally very small and is always less than 50 mg/l of the water being treated. It is added to the lime-soda mixture. The following improvements are obtained:
- 1) Magnesium is precipitated more efficiently, thus preventing, after precipitation, a difficulty associated with precipitation softening;
 - 2) Less time is required to complete the softening reactions;
 - 3) The hardness of the softened water is reduced to less than 20 mg/l in terms of calcium carbonate;
 - 4) Sedimentation is accelerated, and a softened water of low suspended solids is passed to the filters; and
 - 5) Silica content of the softened water is generally reduced.

Rapid flocculation and sedimentation may be used to reduce the retention time, and this is valuable where a plant has to be over-loaded. Another refinement which improves the characteristics of a softened water is the establishment, in the softener, of a blanket of sludge through which the chemicals and the water are made to pass after leaving the mixing zone. Provided no short-circuiting takes place, a water of lower hardness and with less suspended solids may be produced. Another improvement with regard to precipitation softening is 'sludge return' or 'sludge recirculation'. A small quantity of sludge is continuously withdrawn from the sludge zone of the softener and added to the ingoing mixture of water and reagents. The return sludge gives a seeding effect to both flocculation and precipitation and results in better sedimentation and better softening.

- d) *Partial softening* — When a fully softened water is not required, it may be partially softened by treatment with hydrated lime alone to precipitate a major part of the carbonate hardness, according to the degree of softening required.

- e) *Hot softening* — The efficiency of any precipitation process of water softening increases considerably with rise in temperature but the degree of improvement is most marked in the lower temperature range (up to about 50°C). The heat may be derived from waste steam, or live steam, or water drawn from the boiler. If the boiler water is returned to the softener, some modification of chemical charges will be required. Boiler water containing sodium orthophosphate sometimes retards the softening reactions when the temperature at the softener is below 70°C and pH is less than 9.

5.1.1.3 *The base exchange method* — This is the name given to the original method of softening water by zeolites. The name is still applied to the general process whereby sodium is substituted for another metal by means of exchange materials not necessarily of the zeolite class. Calcium and magnesium are retained by the exchange material and an equivalent amount of sodium salts passes out with water leaving the exchange unit. Once the exchange capacity is exhausted, regeneration is carried out with a strong solution of sodium chloride. By this process, sodium is replaced in the exchange material, calcium and magnesium chloride pass out to drain, and the cycle can be restarted. The advantages of the base exchange method of softening are that there is no sludge to be disposed of; that it can be operated under pressure; and that it is simple in operation. However, in general the quantity of water wasted in regeneration is considerable and there are certain other disadvantages also. With precipitation softening, the dissolved solids of the water are reduced but, with the base exchange method, they are slightly increased and all carbonate hardness salts appear as sodium bicarbonate. Thus the alkalinity of the raw water is unaltered. Generally a base exchange softened water is more corrosive to iron and steel than water in the unsoftened state and a softened water containing a high sodium bicarbonate content may be unsuitable for some purposes, for example, laundry or boiler feed. These disadvantages can be overcome by the use of a split stream process which consists of dividing the water into two streams. One passes through a cation exchange resin in sodium form as in a base exchange process and the other through another cation exchange resin in the hydrogen form. The two treated streams are mixed and aerated to remove carbon dioxide. This process produces water of low dissolved solids and of any desired alkalinity. Many modifications of this process are available for various characteristics of the raw water.

5.1.2 *Treatment in the Locomotive* — Treatment in the locomotive is effected by adding the necessary chemicals to the water in the tender. In some cases, solution of the chemicals is pumped directly into the boiler. There are different types of treatment applied in the locomotive tender.

5.1.2.1 In one of these, sodium carbonate, trisodium phosphate and tannin are used in the ratio 3 : 6 : 1. The sodium carbonate reacts with non-carbonate hardness. Tannin reacts with dissolved oxygen and prevents corrosion and also conditions the precipitates into a smooth-flowing non-sticking sludge.

5.1.2.2 In another type of treatment, only sodium carbonate and tannin are used. In this case, the carbonate hardness is allowed to precipitate by itself at the high temperature of the boiler and sodium carbonate reacts with non-carbonate hardness. Tannin reacts with dissolved oxygen and coats the precipitated particles, preventing their interlocking. The soft pliable nature of the precipitate is maintained due to the large proportion of water in it and it does not bake on the boiler during operation. The coating is not confined to the impurities but also takes place on all internal metal surfaces coming in contact with water, giving a thin heat-conducting film which acts as a shield against corrosion. Since the impurities originally present in the water and the solids resulting from crystallization are removed with the gel when coagulation takes place, priming is also reduced.

5.1.2.3 In a third type of treatment, especially when no non-carbonate hardness is present, only tannin is added. The carbonate hardness precipitates by itself and tannin prevents corrosion and conditions the sludge.

5.1.2.4 Certain antifoam agents (various polyamides) are now used in addition to the above chemicals to retard priming and foaming. By the use of these compounds, much higher concentrations of dissolved and suspended solids can be tolerated in the boiler water without any priming or foaming taking place.

6. CONTROL OF TREATMENT

6.1 Testing — It is absolutely necessary that the raw water, softened water, feed water and boiler water are tested at regular intervals and records maintained. The routine tests on raw and softened water are few and simple, and it should be the duty of some responsible person to examine these results, interpret them and make necessary regulation in the chemical charges.

6.1.1 The water softening plant should be kept clean and chemical proportioning gear and other mechanisms in good mechanical order. The softener-reaction tanks should be regularly desludged. The softener should, on no account, be operated above the maximum rating advised by the manufacturer.

6.2 Computation of Initial Dosage of Chemicals — In order to guide the user, simple directions for computing the correct initial dosage of

chemicals for treatment of water are given below. This computation is based on regular chemical analysis of water and not on the control tests only (given in Appendix A). For detailed methods of test reference may be made to relevant clauses of IS : 3025-1964* as given below:

<i>Characteristic</i>	<i>Method of Test</i>
a) Carbonate hardness	17 of IS : 3025-1964*
b) Magnesium hardness	Deduct calcium content (as CaCO_3) determined according to 33.2 of IS : 3025-1964* from total hardness determined according to 16.1 of IS : 3025-1964*
c) Free carbon dioxide	42 of IS : 3025-1964*
d) Non-carbonate hardness	17 of IS : 3025-1964*

6.2.1 Chemicals for Precipitation Softening — The quantities given below are based on stoichiometric ratios of chemical reactions involved. In actual practice, a small excess over the theoretically required amount is found necessary to obtain the best results and to maintain the recommended alkalinity in feed water. In general a 5 percent excess is recommended. Where necessary, the charge may be further adjusted, as required, to obtain the desired results.

6.2.1.1 The quantities recommended are for pure chemicals. Commercial samples of lime vary considerably in their available lime content and this should be taken into consideration when calculating the dose. Same observations also apply to soda ash and sodium aluminate.

a) *Lime*

1) *As Quicklime*

Quicklime to be added,

$$\text{kg/1 000 litres} = 0.000\ 56 \left[\text{carbonate hardness (as } \text{CaCO}_3 \text{) mg/l} + \text{magnesium hardness (as } \text{CaCO}_3 \text{) mg/l} + \text{free carbon dioxide (as } \text{CaCO}_3 \text{) mg/l} \right]$$

2) *As Hydrated Lime*

Hydrated lime to be

$$\text{added, kg/1 000 litres} = 0.000\ 74 \left[\text{carbonate hardness (as } \text{CaCO}_3 \text{) mg/l} + \text{magnesium hardness (as } \text{CaCO}_3 \text{) mg/l} + \text{free carbon dioxide (as } \text{CaCO}_3 \text{) mg/l} \right]$$

*Methods of sampling and test (physical and chemical) for water used in industry.

b) *Soda Ash*

Soda ash to be added,
 kg/1 000 litres = 0.001 1 [non-carbonate hardness
 (as CaCO_3) mg/l]

c) *Sodium Aluminate*

1) Up to total hardness
 (as CaCO_3) of 200 mg/l,
 sodium aluminate to be
 added, kg/1 000 litres = 0.02

2) Total hardness (as
 CaCO_3) above 200 mg/l,
 sodium aluminate to be
 added, kg/1 000 litres = 0.03

6.3 In order to calculate the doses of chemicals for internal treatment, the raw water shall be tested for hardness, alkalinity, sulphates, dissolved solids and nitrates. The methods of testing feed water and boiler water are given in Appendix A.

6.4 It will be seen that due to different types of treatment, the control of treatment in the boiler varies depending on the type of treatment and the analysis of the boiler water, as given in **6.4.1** to **6.4.4**.

6.4.1 When sodium carbonate along with other chemicals is used, the alkalinity to phenolphthalein and caustic alkalinity in the boiler water are kept fairly high, say, up to 15 and 10 percent respectively of the dissolved solids. The dissolved solids are maintained below 2 000 to 5 000 mg/l if antifoam compounds are not used. With a view to controlling caustic embrittlement, it is necessary to test the ratio of nitrates or sulphates to caustic soda in boiler water.

6.4.2 If only sodium carbonate is used, the total alkalinity is generally maintained above 160 mg/l.

6.4.3 If only tannin is added, it is ensured that some tannin is present in the boiler water. The total alkalinity is maintained above 160 mg/l.

6.4.4 In all the above cases except where treatment is by tannin only, hardness is kept at zero. The total dissolved solids are maintained below 2 000 to 5 000 mg/l, if antifoam compounds are not used. If any antifoam compounds are used the total dissolved solids may be allowed to rise up to 15 000 to 20 000 mg/l. If the alkalinity decreases, some more sodium carbonate is added. If the total dissolved solids exceed the above limits, the boiler is given a blowdown. Regular blowdown of the boiler has to be followed to keep the total solids and alkalinity within limits.

6.4.5 Some proprietary water treatment processes are available and are used widely. All of them contain chemicals to precipitate hardness, to prevent corrosion of steel, copper and brass, and also sludge conditioners for the production of a smooth and free-flowing sludge. The suppliers of these products provide instructions for their use in the boiler.

7. DECONCENTRATION

7.1 Blowdown

7.1.1 As the boiler water evaporates, the concentration of total dissolved solids increases and would soon reach a point when priming and foaming would take place. This limit varies from 2 000 to 5 000 mg/l. It is necessary to blowdown the boiler regularly to keep down the concentration of dissolved solids in the water. This blowdown is done as a routine at least once every day. If necessary the blowdown is done more often than once a day; generally blowdowns are given at a watering station before leaving the shed and after returning from the trip. This system of blowdown is called 'intermittent' blowdown.

7.1.2 A 'continuous' blowdown is sometimes provided in a locomotive by which a small quantity of water from the boiler is continuously blown out through a valve which is kept always open. This keeps the concentration of the boiler water almost uniform and does not allow it to increase. Continuous blowdown is now going out of favour.

7.2 Boiler Washing

7.2.1 Even when blowdown is practised regularly, it is necessary that the boiler is washed and filled with fresh water at regular intervals. The interval depends upon the character of the feed water it takes on its run and the treatment it receives.

7.2.2 The boiler is washed either cold or hot. In the cold wash, the boiler is allowed to grow cold by standing aside for a few hours. The water is then drained, the boiler washed with cold water and refilled with fresh water.

7.2.3 In the hot process the boiler is laid aside for a few hours till the pressure is reduced. It is then blown down rapidly and washed with hot water. Hot water is filled in when the boiler is ready for operation again.

8. CHEMICAL COMPOSITION OF WATER FOR LOCOMOTIVE BOILERS AND FREQUENCY OF CONTROL TESTS

8.1 Recommended Chemical Composition of Water in the Boiler —
The information is given in Appendix B.

8.2 Frequency of Control Tests — The frequency of control tests for various types of treatment has to be evolved according to the needs based on experience and study.

APPENDIX A

(Clause 6.2)

CONTROL TESTS FOR WATER FOR LOCOMOTIVE BOILERS

A-0. GENERAL

A-0.1 This appendix deals with only such methods as are required for routine tests for controlling the quality of boiler water for boiler, and which are not given in IS : 3025-1964*.

A-0.2 Quality of Reagents — Unless specified otherwise, pure chemicals and distilled water (*see* IS : 1070-1977†) shall be employed in tests.

NOTE — 'Pure chemicals' shall mean chemicals which do not contain impurities that affect the results of analysis.

A-1. SAMPLING

A-1.1 Sampling shall be done following the general directions given in 2 of IS : 3025-1964*. In particular, the following points shall be observed :

- a) It is necessary that a stainless steel or Monel metal coil is fitted on the sampling cock so that the temperature of the water sample will be well below the boiling point at atmospheric pressure and there is no risk of aeration and concentration due to flashing into steam.
- b) Samples of feed water should be collected from the suction or delivery, as appropriate, of the boiler feed pump; samples of boiler water from the top drum; and samples of condensate from the delivery of the condensate extraction pump. Sample of the boiler concentrate should be taken from the blow off cock before raw water is drawn into the boiler from the tender.

A-2. DETERMINATION OF DISSOLVED SOLIDS IN BOILER WATER

A-2.0 General — Dissolved solids may be determined by any of three methods, namely, gravimetric method, electrical conductivity method or density method.

*Methods of sampling and test (physical and chemical) for water used in industry.

†Specification for water for general laboratory use (*second revision*).

A-2.1 Gravimetric Method — Carry out the test as prescribed in 12 of IS : 3025-1964*.

A-2.2 Electrical Conductivity Method

A-2.2.0 General — For water containing a given mixture of mineral salts the electrical conductance is closely proportional to the dissolved solids. When the samples are known to be free from wide fluctuations in mineral content, the electrical conductance offers a quick means of computing the total dissolved solids. However, this procedure may be used only after ascertaining the appropriate conversion factor:

$$\frac{\text{Electrical conductance}}{\text{Dissolved solids}}$$

for a particular series of samples. A number of samples should be examined gravimetrically for total dissolved solids and their electrical conductance should also be determined. The figures so obtained should be plotted on a graph and the factor or relationship between the two may be arrived at. This factor may be checked and verified after every few months.

A-2.2.1 Electrical Conductance — Carry out the determination as prescribed in 9 of IS : 3025-1964*.

A-2.3 Density Method

A-2.3.0 General — Where an apparatus for measuring electrical conductance is not available, reasonably reliable results can be obtained by density method, particularly when quick results are required. The method is not very accurate but it is found satisfactory for controlling the permissible maximum concentration in the boiler water. Special hydrometers for the determination of dissolved solids in boiler water are also available. These may be used and instructions of suppliers followed. When these are not available ordinary hydrometers may be used.

A-2.3.1 Procedure — Clean the hydrometer and the jar, removing all traces of grease. The hydrometer should be held between the thumb and the finger only at the top of the stem which is above the graduated scale. Pour the sample, filtered if necessary, and preferably cooled to room temperature, into the jar and carefully introduce the hydrometer into it, releasing it at the depth at which it will float. Note the reading when it is steady. Gently push it down a little, allow it to rise and read when it is steady. Take the reading at the lower edge of the meniscus. Note the temperature of the sample.

*Methods of sampling and test (physical and chemical) for water used in industry.

A-2.3.2 Calculation

- a) The density at the observed temperature $t^{\circ}\text{C}$ is reduced to density at 20°C by the following formula:

$$\text{Density at } 20^{\circ}\text{C} = \text{Density at } t^{\circ}\text{C} + 0.0002 (t - 20)$$

- b) Dissolved solids are calculated from the following formula:

$$\text{Dissolved solids, mg/l} = 1.1 \times 10^6 (\text{density at } 20^{\circ}\text{C} - 0.9982)$$

Example:

Density by hydrometer	= 1.0022
Temperature	= 26°C
Density at 20°C	= $1.0022 + (6 \times 0.0002) = 1.0034$
Then dissolved solids	= $(1.0034 - 0.9982) \times 1.1 \times 10^6$
	= $0.0052 \times 1.1 \times 1\,000\,000$
	= 5 720 mg/l

APPENDIX B

(Clause 8.1)

**RECOMMENDED CHEMICAL COMPOSITION OF
BOILER WATER****1. TREATMENT WITH SODIUM CARBONATE, OTHER
CHEMICALS AND TANNIN**

a) Hardness (as CaCO_3), mg/l, <i>Max</i>	Nil
b) Alkalinity to phenolphthalein (as NaOH), mg/l	15 percent of dissolved solids
c) Caustic alkalinity (as NaOH), mg/l	10 percent of dissolved solids with a maximum of 500
d) Ratio Na_2SO_4 /caustic alkalinity (as NaOH)	Above 2.5
<i>or</i>	
Ratio NaNO_3 /total alkalinity (NaOH)	Above 0.4
e) Dissolved solids (without antifoams), mg/l	2 000 to 5 000
f) Dissolved solids (with antifoams), mg/l	15 000 to 20 000
g) Tannin	Present
h) Chloride (as Cl), mg/l, <i>Max</i>	2 000

2. TREATMENT WITH SODIUM CARBONATE AND TANNIN

a) Hardness (as CaCO_3), mg/l, <i>Max</i>	Nil
b) Total alkalinity (as NaOH), mg/l	More than 160
c) Dissolved solids (without antifoams), mg/l	2 000 to 5 000
d) Dissolved solids (with antifoams), mg/l	15 000 to 20 000
e) Ratio Na_2SO_4 /caustic alkalinity (as NaOH)	Above 2.5

or

Ratio NaNO_3 /total alkalinity (as NaOH)	Above 0.4
f) Tannin	Present
g) Chloride (as Cl), mg/l, <i>Max</i>	2 000

3. TREATMENT WITH TANNIN ONLY

a) Tannin	Present
b) Dissolved solids (without antifoams), mg/l	2 000 to 5 000
c) Dissolved solids (with antifoams), mg/l	15 000 to 20 000
d) Total alkalinity (as NaOH), mg/l	More than 160 mg/l
e) Chloride (as Cl), mg/l, <i>Max</i>	2 000

(Continued from page 2)

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